THE EFFECT OF A MAXIMAL STRETCH-SHORTENING CYCLE FATIGUE WORKOUT ON FAST STRETCH-SHORTENING CYCLE PERFORMANCE

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This study examined the effect of a maximal stretch-shortening cycle fatigue workout on the biomechanical performance of rebound jumps that were done 15, 45, 120 and 300 seconds post-fatigue. Thirteen elite level rugby players participated in the study. Rebound jumps were done before and after the workout. All jumps were performed on a sledge and force plate apparatus. Flight time, ground contact time, peak force and leg spring stiffness were the dependent variables. The results indicated that the fatigue workout significantly reduced flight time ($p < 0.001$), peak force ($p < 0.01$) and increased contact time ($p < 0.05$) at the 15 second interval. The efficiency of the stretch-shortening cycle function was reduced. The results also indicate a potentiation effect at the 300-second interval due to a significant increase in peak force and leg stiffness ($p < 0.05$).

KEY WORDS: leg spring stiffness, sledge apparatus, rugby.

INTRODUCTION: The stretch-shortening cycle (SSC) has been defined as a stretching of an active muscle immediately followed by a concentric contraction (Komi, 1984). The stretching of the active muscle allows for a more forceful concentric contraction. The SSC can be divided into slow and fast SSC activities. Slow SSC activities have ground contact times greater than 250ms whereas fast SSC activities have contact times between 100 and 250ms (Schmidtbleicher, 1992). A typical slow SSC activity would be a line-out jump in rugby while sprinting and drop-jumping would represent a fast SSC activity.

The physiological mechanisms behind fatigue are complex and it has been described as a loss of capability to generate force or an inability to sustain further exercise at the required level (Strojnik & Komi, 1987). Traditionally research focused on examining the effect of fatigue on isometric, concentric and eccentric actions. In real life situations, exercise seldom involves a pure form of these actions. More often, movement takes the form of a SSC and thus the SSC fatigue model provides an excellent basis for studying muscle function (Komi, 2000). The majority of previous SSC fatigue studies have concentrated on submaximal fatigue workout intensity levels (Avela & Komi, 1998; Gollhofer et al., 1987a, b; Horita et al., 1999; Nicol & Komi, 1991). According to Komi (1992) following submaximal fatigue workouts ground reaction force curves imply reduced tolerance to stretch loads and a loss in the recoil characteristics of the muscles. Avela and Komi (1998) reported reduced muscle stiffness for drop jumps (DJ) performed after a marathon run resulting in weakened muscle performance and impaired utilization of elastic energy. Gollhoffer et al. (1987 a,b) found increases in the contact times for both eccentric and concentric phases of the SSC exercise post-fatigue. Muscular activation processes were reduced leading to a reduction in the possibilities for effective SSC behaviour.

Only one SSC fatigue study employed a maximal SSC fatigue workout with the aim of investigating possible mechanisms of neuromuscular fatigue (Strojnik & Komi, 1998). The workout involved the subjects completing rebound jumps (RBJ) on a special sledge apparatus until they were unable to maintain a jumping height greater than 90% of their maximum. Past research, however, has not looked at the effect of a maximal SSC fatigue workout on the biomechanical performance of a subsequent fast SSC exercise, like a RBJ. In addition, research has failed to see how long it takes the fast SSC function to recover after a maximal SSC fatigue workout. Consequently the aim of this study was to examine the effect on male rugby players of a maximal fatigue workout on RBJ performed at various recovery intervals post-fatigue. In particular the effect of the workout on flight time (FT), ground contact time (CT), peak ground reaction force (GRF) and leg spring stiffness (k_{vert}) was examined.

METHOD: Thirteen elite male rugby players participated in this study. All subjects were proficient with the technique of drop and rebound jumping and were professional players contracted to the Irish Rugby Football Union. The study had obtained ethical approval from the University of Limerick research ethics committee and written informed consent was obtained from all subjects prior to their participation in the study.

Table 1: Physical Characteristics of the Subjects.

Age (years)	Height (cm)	Mass (kg)
21.4 ± 2.4	182.9 ± 5.8	88.4 ± 8.1

The testing was completed over one session. Sets of one-legged DJ followed by a one-legged RBJ were completed before (baseline) and 15, 45, 120, & 300 seconds after a maximal SSC fatigue workout. The drop height used for the DJ/ RBJ set was 30cm and all subjects were asked to use their dominant leg. Recovery interval was the independent variable. FT, CT, GRF and k_{vert} for the RBJ were the dependent variables. The jumps were performed on a sledge apparatus inclined at 30º as described by Harrison et al. (2004). An AMTI OR6-5 force platform was mounted at right angles to the sledge apparatus and sampled at 1000 Hz, allowing ground force reaction measurements to be obtained for each jump. Instants of initial foot contact, take-off and subsequent landing were obtained via these ground reaction force traces. CT was calculated by finding the time difference between the initial foot contact and take-off. FT was defined as the time difference between the take-off and landing. Peak GRF was the maximum force reading recorded for the ground reaction force traces. A spring-mass model was used to analyse the control of k_{vert}, which has been defined as the ratio of the peak force in the spring, GRF, to the displacement of the spring, ΔL, at the instant that the leg spring was maximally compressed. Due to the spring-like nature of the leg during RBJ, the peak ground reaction force and the peak leg-spring displacement both occur simultaneously at the middle of the ground contact phase (Ferris & Farley, 1997). Stiffness measures were calculated by dividing the peak GRF by the displacement of the chair from landing to full crouch for the RBJ. The SVHS video recordings (50Hz) were digitised using Peak Motus® (Peak Performance Technologies, Colorado, USA) to calculate the displacement of the sledge.

The subjects were instructed to refrain from weight and plyometric training on the day preceding the testing session. Following a general (3 minutes of low-intensity jogging and static stretching of the major leg muscles with stretches held for 15 seconds) and a specific (2 sets of one DJ and one RBJ) warm-up the subjects completed four baseline sets of one DJ followed by a RBJ. The DJ and RBJ technique was explained and demonstrated to the subjects during the warm-up. They were instructed to minimise their contact time on the force platform and maximise their subsequent jump height for both types of jumps. The baseline jump data was then analysed to find the jump height for each RBJ. The jump with the maximum height was selected and 90% of this value was marked on the sledge from a position where the subject was seated in the sledge chair with the leg fully extended. The mean 90% level was 0.36 ± 0.04m. The fatigue workout involved the subject being dropped from a height of 30cm and performing RBJ until they failed to reach the 90% level for three consecutive jumps. One DJ/ RBJ set was completed 15 and 45 seconds and two sets were completed 120 and 300 seconds after the termination of the fatigue workout. A cool-down (light jogging and static stretching) was completed at the end of the testing session.

Statistical Analysis: All statistical analysis was conducted using a software package (SPSS for Windows, Release 11.0.1). Differences between the average of the RBJ baseline scores and the average of the RBJ scores after the different recovery intervals for each dependent variable were evaluated using a 2-way analysis of variance (ANOVA) with repeated measures. The GLM ANOVA had 1 within-subjects factor namely Condition with 5 levels (baseline, 15, 45, 120 and 300 seconds). Alpha was set at the $p < 0.05$ level.

RESULTS: The mean number of jumps performed during the fatigue workout was 49 ± 20 jumps and the duration was 62.2 ± 20.9s. The mean dependent variable scores for the baseline jumps were subtracted from the scores for the jumps done at the different recovery intervals and the results can be seen in figure 1. In this figure the x-axis represents the baseline. The GLM ANOVA results indicated a significant reduction in FT ($p = 0.721X10^{-4}$), increase in CT ($p = 0.007$) and reduction in peak GRF ($p = 0.021$) 15 seconds after the termination of the workout. The difference between the baseline jumps and the jumps done at the 300-second interval showed a significant increase in peak GRF ($p = 0.031$) and k_{vert} ($p = 0.036$). There was also an increase in the mean FT difference and a reduction in the mean CT difference for the 300-second interval, neither of which was significant ($p \geq 0.05$).

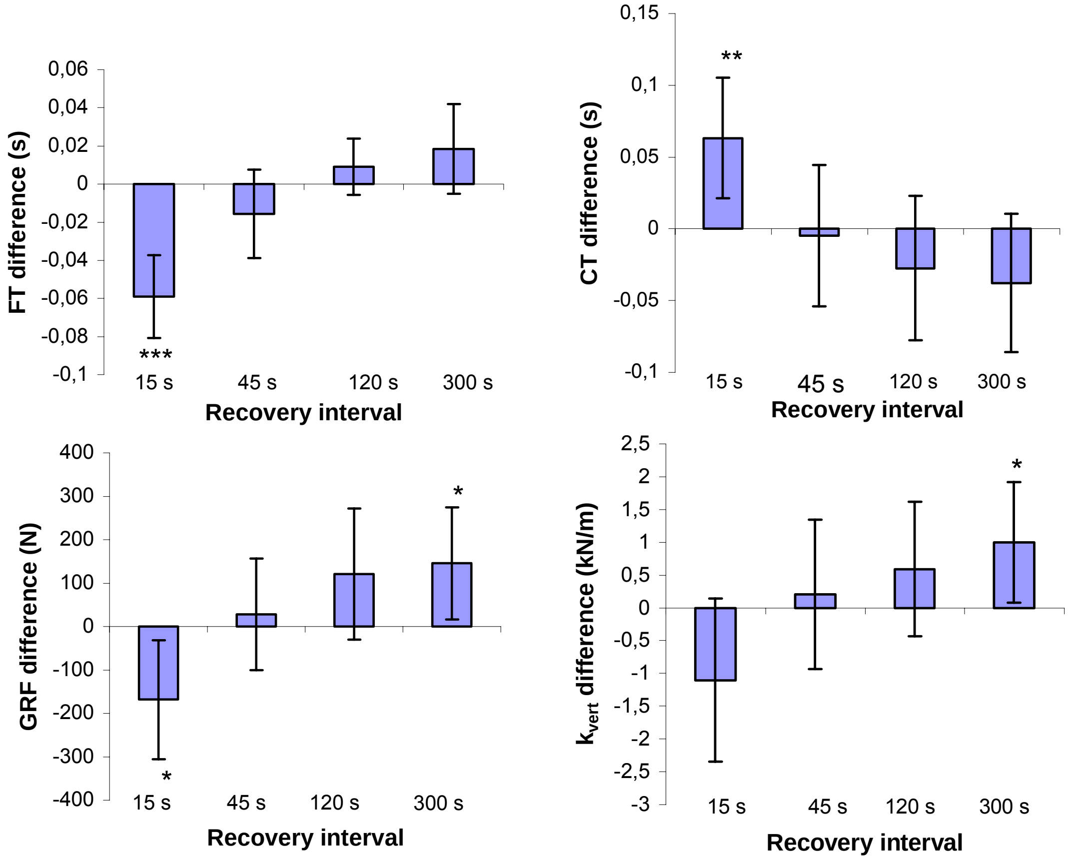

Figure 1: Mean ± 95% confidence interval FT, CT, GRF and kvert difference between the baseline jumps and the jumps done at the different recovery intervals. (*** $p < 0.001$; ** $p < 0.01$, * $p < 0.05$).

DISCUSSION: The dependent variables scores for the 15-second interval demonstrate findings similar to studies that employed submaximal SSC fatigue workouts, such as Avela & Komi (1998), Gollhofer et al. (1987 a,b) and Nicol et al. (1991). Repeated maximum SSC jumping altered the way the RBJ was performed by increasing ground contact time, reducing leg-spring stiffness and reducing peak GRF. The efficiency of the SSC behaviour was decreased and this could be responsible for the performance depression at the 15 second interval as is evident by the significant reduction in FT.

Past submaximal SSC fatigue studies have indicated that recovery from SSC fatigue takes place in a bimodal fashion, involving a dramatic decline post-fatigue followed by a short-lasting recovery and than a subsequent secondary decline (Horita, 1999; Komi, 2000). In the present study a similar trend was evident. Following the initial decline in scores the trend is for improvement at each of the subsequent intervals with a significant enhancement in GRF and kvert at the 300-second interval. This indicates that there is a potentiation effect from the fatigue workout as research has demonstrated that increases in kvert are associated with faster running stride frequencies and velocities (Arampatzis et al., 1999; Farley et al., 1996). Comyns et al. (2005) reported a similar potentiation effect on the biomechanical performance of a fast SSC exercise due to a prior contractile activity. The results indicate that at the 300-second interval the biomechanics of the RBJ performance are altered with the jump being performed quicker and with a shorter and stiffer leg spring action.

CONCLUSION: This study shows that following a maximal SSC fatigue workout there is a significant reduction in GRF, FT, and an increase in CT. kvert is reduced but not significantly. This indicates that there is a loss of efficiency of the SSC function. There is a trend for recovery at the subsequent recovery intervals with significant improvements in GRF and kvert seen at the 300 second interval. These changes indicated that there is an enhancement in RBJ performance at this interval as the RBJ is performed with a stiffer and more elastic leg spring action.

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